



Encyclopedia

Advanced Petroleum-Based Fuels—
Diesel Emissions Control (APBF-DEC) Project

APBF-DEC Project Encyclopedia

April 2002

NOTE: This encyclopedia defines the acronyms, words, terms, and phrases used in the APBF-DEC project and its predecessor, the Diesel Emissions Control-Sulfur Effects (DECSE) project. Other entries provide background for the project work. APBF-DEC participants are identified by an asterisk (*). Words in the text that are in *italic/bold* type are further defined elsewhere in the encyclopedia, in alphabetical order. The encyclopedia will be updated at regular intervals. If you have updates, corrections, or additions to this encyclopedia, please send them to Helen Latham, APBF-DEC Communications (lathamh@battelle.org; Battelle, 505 King Ave., Columbus, OH 43201-2693; Phone 614-424-4062; Fax 614-424-5601).

Adsorption – The assimilation of a gas or vapor onto a solid surface.

AFDC – Alternative Fuels Data Center, the U.S. Department of Energy's repository for information about alternative fuels, managed by the National Renewable Energy Laboratory (NREL) at Golden, CO (<http://www.afdc.nrel.gov/>).

After-treatment devices – Advanced after-treatment technologies that can reduce **CO**, **HC**, **NO_x**, and **PM** emissions from diesel engines. (See also *emission control technologies*.)

AFV – Alternative fuel vehicle.

Aging – The process of intentionally accelerating the wear on emission control technologies to simulate intense operation in preparation for tests, either by physical or chemical means.

Alternative fuels – Fuels that can replace ordinary gasoline or diesel fuel. Alternative fuels include electricity, compressed natural gas (CNG), liquefied natural gas (LNG), hydrogen, methanol, ethanol, propane, and *biodiesel*. Alternative fuels may have energy efficiency and pollution reduction features. The 1990 Clean Air Act encourages the development and use of alternative fuels in vehicles.

***American Chemistry Council** – Participant in the APBF-DEC project.

APBF-DEC – Advanced Petroleum-Based Fuels—Diesel Emissions Control project. APBF-DEC is an industry/government project to identify and evaluate (1) the optimal combinations of low-sulfur diesel fuels, lubricants, diesel engines, and emission control systems to meet projected emission standards for the 2001 to 2010 time period and (2) properties of fuels and vehicle systems that could lead to even lower emissions beyond 2010.

***API** – American Petroleum Institute, an APBF-DEC participant.

ASTM – American Society for Testing and Materials.

ATL – Automotive Testing Laboratories, the subcontractor located in East Liberty, OH, that is researching the effects of *lubricant* composition on emissions and performance of advanced emission control technologies.

ATV – Advanced technology vehicles.

Base fuel – A base fuel containing 0.6-ppm sulfur is being used in the *APBF-DEC* project. The base fuel is being “doped” (see *doping*) to provide other fuels in the tests (i.e., 8-, 15-, and 30-ppm sulfur).

Biodiesel – An alternative fuel made from non-petroleum feedstocks, such as oil seed crops (e.g., soybeans, canola seeds, or other plant-derived sources), that can be used as is or blended with conventional diesel fuel to reduce emissions without major modifications or significant effects on engine performance.

BPT – Balance point temperature, commonly used to describe the temperature at which the rate of particulate matter generated is equal to the rate of regeneration in a *diesel particle filter*.

BSCO – Brake-specific carbon monoxide (*CO*).

BSFC – Brake-specific fuel consumption.

BSHC – Brake-specific hydrocarbons (*HC*).

BSNO_x – Brake-specific oxides of nitrogen (*NO_x*).

BSPM – Brake-specific particulate matter (*PM*).

C – Celsius

CAFE – Corporate Average Fuel Economy, which was introduced in 1975 to reduce gasoline consumption by requiring auto manufacturers to meet fuel efficiency targets and to produce and promote more efficient models.

***CARB** – California Air Resources Board, a participant in the *APBF-DEC* project.

Catalyst – A substance or device that causes or accelerates a chemical change without itself being changed; in the DECSE program, catalysts intended for diesel exhaust were used in four tests (see *particle trap/filter*, *NO_x adsorber*, *lean NO_x catalyst*, and *oxidation catalyst*).

CB-DPF – Catalyzed-based diesel particulate filter.

Cetane – A colorless liquid (C₁₆H₃₄) that is a pure hydrocarbon and is used as a solvent. Cetane, which is the common name for hexadecane, is a rapidly-igniting, easily decomposing hydrocarbon that, when used in diesel fuels, stimulates quick ignition.

Cetane number (or cetane rating) – The cetane number or rating is used to measure the quality of a diesel fuel. Cetane represents 100 on the reference scale established to measure the ignition quality of diesel fuel on ignition delay. Using a diesel fuel with a higher cetane number improves cold starting, ignites the engine more quickly, minimizes engine knock and soot, and reduces engine stress.

CI engines – Compression ignition or diesel-cycle engines are used in most heavy vehicles, such as highway trucks, because of their high efficiency and durability compared to spark-ignited

gasoline engines. Diesel engines do not use a spark plug to ignite the air-fuel mixture in the combustion chamber.

CIDI – Compression-ignition, direct-injection engines, where fuel is injected directly into each engine cylinder and NO_x emissions are reduced. The most efficient CIDI is a diesel engine, which is ignited through the heat of compression. The higher heat resulting from the increased pressure in the combustion chamber makes the air-fuel mixture ignite, thus the *compression-ignition* term. Less fuel is injected into the cylinder, resulting in less throttling losses. (See also *lean burn*.)

CO – Carbon monoxide, a colorless, odorless, poisonous gas produced by the incomplete burning of carbon-based fuels, including gasoline, oil, or wood.

CO₂ – Carbon dioxide, a product of complete combustion of hydrocarbon fuels.

Compression Ignition or CI – A type of ignition that initiates combustion in a diesel engine. The rapid compression of air within the cylinders generates the heat required to ignite the fuel as it is injected.

Control technology/control measures – Systems, equipment, processes or action used to reduce air pollution. The best available control technology/control measure will be required in *nonattainment areas* for **CO**, **NO_x** and **PM**.

CPSI – Cells per square inch.

CRADA – Cooperative Research and Development Agreement, an agreement to conduct research and development activities entered into by a federal agency and a "collaborator," such as a private company, laboratory, or consortium.

CRC – Coordinating Research Council.

Criteria air pollutant – a group of common air pollutants regulated by EPA on the basis of criteria, i.e., information on health and/or environmental effects of pollution.

CVS – Constant volume sampling.

DDC – Detroit Diesel Corporation.

DECSE – Diesel Emissions Control – Sulfur Effects Project. The DECSE project was conducted to determine the impact of fuel sulfur levels on emission control systems, which could be used to lower emissions of NO_x and PM from diesel engines in the years 2002 to 2004. The project was directed by representatives of **DOE**, two of its national laboratories, and manufacturers of diesel engines and exhaust emission control systems. DECSE was the predecessor to the **APBF-DEC** project.

Degreening – Exposing a new emission control device to exhaust gas, to achieve stable operations.

DI – Direct injection engine. (See **CIDI**.)

Diesel engine – An internal-combustion engine that uses the heat of highly compressed air to ignite a spray of fuel introduced after the start of the compression stroke. (Named after Rudolf Diesel [1858-1913], the engine's inventor.)

Diesel fuel – Fuel that can be burned in a *diesel engine*.

Diesel oxidation catalyst (DOC) – Reduces *hydrocarbon, carbon monoxide*, and *particulate matter* by oxidation over *catalysts* loaded with precious and base metals.

DME – Dimethyl ether, a derivative of natural gas, is one of the new, synthetic fuels being studied for use in compression ignition engines, such as diesels, to reduce emissions. DME has excellent CIDI fuel characteristics, produces almost no particulates on combustion, and has no offsetting increases in other emissions. But DME is a gas, so there are handling and infrastructure issues. (See also *Fischer-Tropsch fuel* and *new fuels*.)

DOC – See *diesel oxidation catalyst*.

***DOE** – U.S. Department of Energy, the federal agency conducting research on advanced combustion, exhaust after-treatment, and diesel fuel formulations to enable compression ignition or diesel engines to meet emission standards that may be in place beyond 2004. The Advanced Petroleum-Based Fuels project (*APBF-DEC*) is conducted through the DOE Office of Transportation Technologies' (*OTT*) Office of Heavy Vehicle Technologies (*OHVT*) and Office of Advanced Automotive Technologies (*OAAT*).

Doping – The process of adding to the fuels being tested the proper proportions of other chemicals known to be present in most diesel fuels. For the APBF-DEC and DECSE projects, this process added varying levels of sulfur to the *base fuel*.

DPF – Diesel particle filter, a technology that can remove particulate matter from a diesel engine's exhaust. Using advanced fuel formulations and an **SCR** or one of three types of **NO_x adsorbers**, or directly retrofitted to the existing engine, the DPF can reduce regulated, unregulated, and toxic emissions. Two types of DPFs (and SCRs) are being evaluated in the *APBF-DEC* project.

ECU – Electronic control unit. An engine management technology that controls the functions of all vehicle systems.

EGR – Exhaust gas recirculation system. An emission control strategy that redirects some of the cooled exhaust gases back into the engine, replacing some filtered air. The EGR reduces peak combustion temperatures and can reduce **NO_x** emissions. Proper rate settings are necessary to ensure **NO_x** reductions without significant effects on **PM**, **HC**, or other gaseous pollutants.

***EMA** – Engine Manufacturers Association, a participant in the APBF-DEC project.

Emissions – Release of pollutants into the air from a mobile or stationary source, i.e., sources emit pollutants. Mobile sources carry sensors that monitor the function of the **emission control systems (ECS)**. Some large stationary sources of pollutants are required to install continuous emission monitoring systems and to continuously measure the pollutants released.

Emission control systems (ECS) – Systems that significantly reduce tailpipe emissions of one or more pollutants. For the DECSE and APBF-DEC projects, these technologies were called upon to perform reliably, be durable enough to allow degradation testing, and be economically viable both in cost and fuel economy effects. In general, these systems include control devices for particulate matter and **NO_x**. Particulate matter control devices function with two general types of processes. The first involves oxidation of hydrocarbons in the vapor phase that would later condense or adsorb on particles (see *oxidation catalyst*). The second type removes particulate matter through the principle of filtration (see *particle trap/filter*). **NO_x** control devices include the *lean-NO_x catalyst* and *NO_x adsorber catalyst*.

EO – Engine-out.

***EPA** – U.S. Environmental Protection Agency, a participant in the APBF-DEC project.

EPAct – The Energy Policy Act passed by Congress on October 24, 1992, with the goals of enhancing the nation's energy security and improving environmental quality. The act includes provisions addressing all aspects of energy supply and demand, including energy efficiency, alternative fuels, and renewable energy, as well as more traditional forms of emerging, such as coal, oil, and nuclear power. Several part of the act were designed to encourage the use of alternative fuels, not derived from petroleum, that could help reduce dependence on imported oil for transportation. For further information go to the DOE Web site (<http://www.ott.doe.gov/epact/>).

EPEFE – European Programme on Emissions, Fuels, and Engine Technologies, which conducted a study of both diesel and gasoline. The purpose of the study was to identify the relationships between fuel properties and engine vehicle technologies to determine the effectiveness of various fuel and vehicle strategies to reduce emissions.

Exhaust – The products of combustion. Diesel exhaust is a complex mixture of many constituents and can have a range of temperatures, pollutant concentrations, and particle sizes. Exhaust emissions will be characterized in terms of criteria pollutants [e.g., *particulate* mass, nitrogen oxide (NO_x), hydrocarbons (*HC*), carbon monoxide (*CO*)] and other substances [e.g., sulfur dioxide (SO_2), carbon dioxide (CO_2), soluble fraction of particulate matter (*PM*)].

Feedstocks – Hydrocarbons that can be used/blended to create a fuel.

FEP – Fuel economy penalty.

FEV – FEV Engine Technology, contractor conducting tests of an exhaust aftertreatment system, one of the three NO_x adsorber/DPF tests in the APBF-DEC project.

FLRS – Full-load, rated speed.

FreedomCAR – A research and development partnership between the U.S. Department of Energy and the U.S. Council for Automotive Research (USCAR). USCAR member companies include DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation. FreedomCAR is focused on the development of long-range, high-risk technologies, that will pave the road toward petroleum free, emissions free transportation.

F-T (Fischer-Tropsch) fuels – Diesel fuels can be made from natural gas using a method known as the Fischer-Tropsch process. F-T fuels are liquid, not a gas, at ambient conditions. They have a high cetane number and effectively no sulfur content. In the future, F-T fuels may be economically competitive with current “clean” diesel fuels. They can be used in existing diesel engines, and they can be dispensed by existing infrastructure, i.e., pumps and storage systems used for current diesel fuels.

FTIR – Fourier Transform Infra-red Spectroscopy. An analytical technique used to identify organic (and in some cases inorganic) materials. The FTIR measures the absorption of various infrared light wave lengths by the material being studied. The infrared absorption bands identify the molecular components and structures.

FTP – Federal test procedure, defined by *EPA* to characterize engine or vehicle emissions during transient operation.

g/bhp-hr – Grams per brake horsepower-hour, a brake-specific unit generally used to characterize emissions from heavy-duty engines.

GHG – Greenhouse gas.

Hazardous air pollutants (HAPs) – Chemicals that cause serious health and environmental effects. Health effects include cancer, birth defects, nervous system problems, and death due to massive accidental releases such as what occurred at the pesticide plant in Bhopal, India. HAPs are released by sources such as chemical plants, dry cleaners, and motor vehicles.

HDE – Heavy-duty engine.

HFRR – High frequency reciprocating rig (ASTM D6079), a device used to measure the *lubricity* of diesel fuel, in which a hardened steel ball oscillates across a steel plate under a fixed load for 75 minutes. The point of contact between the ball and plate is immersed in the sample. The size of the resulting wear scar on the steel ball is a measure of the sample's lubricity.

HSDI – High speed, direct injection engine.

HT – High-temperature.

Hydrocarbon (HC). Any of many organic compounds containing only carbon and hydrogen, such as benzene and methane.

IDI – Indirect injection engine.

L – Liter.

Lean burn – A more efficient engine (either spark-ignition or diesel) that uses more air than fuel, compared to today's engines. Lean burning engines also use less fuel and have lower HC and CO emissions. But the associated catalytic converters have more difficulty reducing NO_x emissions, especially with high sulfur fuels.

Lean-NO_x catalyst – A catalyst capable of chemically reducing NO_x to N₂ in the presence of oxygen is called a lean-NO_x catalyst. Such a catalyst would promote a chemical reaction in which NO forms molecular nitrogen and molecular oxygen. It is difficult to find a catalyst for this reaction that is effective under the conditions present in diesel engine exhaust. Lean-NO_x catalysts can be classified as either a base metal or a precious metal. Base metal catalysts include zeolite-type catalysts. The base metal catalysts operate at “high” temperatures of 300-350°C. They offer selective conversion of NO_x to nitrogen and oxygen. However, stability remains a problem; they are susceptible to hydrothermal deactivation of the zeolite. Precious metal catalysts include platinum-based catalysts. They operate at a lower temperature, i.e., 200-300°C, with effectiveness peaking at about 250°C. They are more stable than base metal catalysts, but they can convert NO_x to nitrous oxide (N₂O) and will oxidize SO₂ to sulfate.

Little, A.D. – A subcontractor for the *SCR/DPF* project, assessing the potential to develop a *urea* distribution infrastructure.

Low-sulfur fuel – This fuel is already available in California and other states—as well as in much of Europe and Japan—but most other states in the U.S. use fuel with higher levels of sulfur. Low-sulfur fuel allows advanced emission control devices, especially lean-burn catalysts, to function more effectively. High sulfur levels in fuels reduce the effectiveness and durability of catalytic converters. The U.S. EPA has mandated that fuel containing <15 parts per million sulfur be used starting in June 2006.

LT – Low-temperature.

Lubricants – Engine oil that reduces friction when applied as a surface coating to moving parts. Lubricants typically contain a mineral or synthetic basestock and a blend of additives that extend the oil's life and enhance performance.

Lubricity – A measure of lubricating quality, typically when referring to a fuel. Certain fuel injection equipment components that are lubricated by the fuel can be damaged when fuels with poor lubricity are used. Lubricity is commonly determined by the **HFRR** or **SBOCLE** tests.

***MECA** – Manufacturers of Emission Controls Association, a participant in the APBF-DEC project.

MOBILE – A comprehensive mobile source emissions model developed and currently being updated by the U.S. Environmental Protection Agency. The model provides average in-use fleet emissions factors for pollutants for different vehicle categories operated under various conditions as specified by the model user.

Mode – In terms of engine test cycles, a mode is an engine operating condition defined by combination of engine speed (rpm) and load (torque).

MPG – Miles per gallon.

MY – Model year.

N₂ – Nitrogen

New fuels – Researchers are developing new fuels and testing ways to adapt existing fuels or chemical compounds for use as fuels to help meet future lower emission standards. An example of an existing fuel being considered is Fischer-Tropsch (**F-T**), named for the two German scientists who invented a method of liquifying natural gas. Examples of chemical compounds that may be adapted for use in engines are DME (dimethyl ether), DMM (dimethoxymethane), and DOMDME (di-oxymethylene dimethyl ether). Early tests indicate that using these fuels reduces particulates and **NO_x** emissions better than does the reformulated petroleum diesel fuel used in California. One of the issues to be resolved is how to provide the infrastructure so these new fuels can be made available to users. (See also *reformulated fuels*.)

NMHC – Non-methane hydrocarbons. The sum of all hydrocarbon emissions contributing to air pollution except methane.

Noble metal – Any metal or alloy of comparatively high value or relatively superior in certain properties, especially resistance to corrosion or infusibility, such as gold, silver, rhodium, iridium, or platinum.

NO – Nitric oxide. Gas formed by combustion under high temperature and high pressure in an internal combustion engine. NO is a precursor of ground level ozone pollution, or smog.

NO₂ – Nitrogen dioxide.

NO_x – Nitrogen oxides. A **criteria air pollutant**. Nitrogen oxide is produced from burning fuels such as gasoline and coal. NO_x plus hydrocarbons plus sunlight causes ozone and irritants (i.e., smog).

NO_x adsorber catalyst – The NO_x adsorber catalyst is a flow-through exhaust emission control device with the potential to significantly reduce nitrogen oxide (**NO_x**), hydrocarbon (**HC**), and carbon monoxide (**CO**). The adsorber functions by first storing (adsorbing) NO_x and then

catalytically reducing the stored NO_x under rich conditions. The NO_x adsorber device does not operate continuously; it cycles between adsorption and reduction. Combined with a **DPF**, the system also can oxidize the diesel particulate matter (**PM**).

***NPRA** –National Petrochemical and Refiners Association, a participant in the **APBF-DEC** project.

***NREL** – National Renewable Energy Laboratory in Golden, CO, a DOE national laboratory supporting the APBF-DEC project.

O₂ – Oxygen.

OAAT** – Office of Advanced Automotive Technologies in DOE's Office of Transportation Technologies (OTT), a participant in the **APBF-DEC** project. **please see note in e-mail**

OEM – Original equipment manufacturer.

OHVT** – The Office of Heavy Vehicle Technologies in DOE's Office of Transportation Technologies (OTT). OHVT manages the **APBF-DEC** project. **please see note in e-mail**

OICA – Identifier used to designate a test cycle developed during European work. OICA is the acronym for the Organization Internationale des Constructeurs d'Automobiles (International Organization of Motor Vehicle Manufacturers).

ORNL – Oak Ridge National Laboratory, a DOE national laboratory supporting the APBF-DEC project.

OTT – DOE's Office of Transportation Technologies.

Oxidation catalyst – A flow-through device that oxidizes **hydrocarbons**, **carbon monoxide**, and **particulate matter** in a vehicle exhaust over a precious metal catalyst.

OXY or Oxygenates – Oxygen-rich compounds—such as ether—added to vehicle fuels to make them burn more completely, thus significantly reducing unburned **hydrocarbons**, **carbon monoxide**, and other toxic tailpipe emissions. Examples include methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), ethanol, and biodiesel.

Particle trap/filter – **Particulate matter** can be removed from exhaust through the use of filters, but to keep the filter operating, it must be “regenerated,” i.e., the particulate matter must be removed from the filter before excessive pressure drop develops. Particle traps include catalyzed soot filters, which contain a filter with a catalyst that promotes oxidation. The catalyst aids in regeneration by lowering the temperature at which ignition of the particulate matter occurs. The catalyst may be applied to the filter, in front of the filter, or it may be applied by adding a substance such as compounds of cerium, platinum, or iron to the fuel. There are also catalyzed soot filters with active generation. These function by adding heat to the filter or changing the operation of the engine to raise the temperature of the exhaust gases.

Particulate matter – Includes dust, soot, and other tiny bits of solid materials that are released into the air. Particulate matter is produced by many sources, including burning diesel fuels, garbage incinerators, mixing and applying fertilizers and pesticides, steel making, and using fireplaces and woodstoves.

Plasma exhaust emission control devices – These devices use energy in an electrical plasma to encourage the establishment of a new molecular composition. This technology is not fully

developed. Early results show that it can have a significant impact on NO_x and PM emissions, but that the fuel economy penalty for the energy necessary to power the after-treatment device may be significant.

PM – See *particulate matter*.

PNGV – Partnership for the Next Generation of Vehicles was formed in September 1993 between the U.S. Government and the U.S. Council for Automotive Research (*USCAR*). PNGV's purpose was to develop affordable, midsize, family sedans capable of achieving up to 80 miles per gallon with very low emissions, while providing the performance and safety of today's vehicles. PNGV was discontinued in January 2002 and replaced by a new program, the *FreedomCAR*.

Pollutants – Unwanted chemicals or other materials found in the air. Air pollutants can occur as gases or vapors, dust, smoke or soot. Pollutants can harm health, the environment, and property.

PPM – Parts per million.

R&D – Research and development.

Regeneration – Restoring an emission control device to its original condition. For diesel particle filters, this entails removing collected **PM** by oxidation. For catalysts impaired by sulfur-containing compounds (or other species), this means removing those compounds from the catalyst's surface.

Ricardo, Inc. – Test laboratory in Burr Ridge, IL, that is the subcontractor for the heavy-duty NO_x *adsorber/DPF* project.

RPM – Engine speed in revolutions per minute.

SBOCLE – The Scuffing Load Ball on Cylinder Lubricity Evaluator, a test that measures fuel *lubricity* by determining the maximum load that can be applied without causing scuffing. A ball-on-cylinder apparatus immersed in the sample is run under a series of loads to closely bracket the highest non-scuffing load the sample can tolerate.

***SCAQMD** – The South Coast Air Quality Management District, a participant in *APBF-DEC*.

SCR – Selective catalytic reduction technology, an emission reduction device that, combined with a diesel particle filter (**DPF**) and advanced fuel formulations, has the potential to reduce regulated, unregulated, and toxic emissions. Two types of SCRs and DPFs are being evaluated in the APBF-DEC project.

SI – Spark-ignition.

SOF – Soluble organic fraction of particulate matter. The quantity and composition of SOF depends upon the solvent used to extract the SOF.

SO₂ – Sulfur dioxide.

SO₄ – Sulfate.

Steering Committee & Working Groups – The *APBF-DEC* technology experts, researchers, and decision-makers who represent federal and state agencies; national laboratories; trade and professional organizations; automobile and engine manufacturers; emission control companies; and energy/additives companies.

Sulfur (S) – A naturally occurring element that can become a contaminant of crude oil, clog catalytic converters, and increase the pollutants emitted.

SUV – Sport-utility vehicle.

SwRI –Southwest Research Institute, subcontractor in San Antonio, TX, conducting two projects: the *SCR/DPF* technologies test and one of the three *NO_x adsorber/DPF* tests in the APBF-DEC project.

TBN – Total base number, a measure of the alkalinity (acid neutralizing capability) of engine oil.

THC – Total hydrocarbons.

TWC – Three-way catalyst.

ULEV – Ultra-low emissions vehicle.

Urea – An aqueous solution that, when heated, can produce ammonia that can react to reduce NO_x to elemental nitrogen in an SCR device.

USCAR – The United States Council for Automotive Research—the umbrella organization of DaimlerChrysler, Ford, and General Motors—was formed in 1992 to further strengthen the technology base of the domestic auto industry through cooperative, pre-competitive research. In 1993 ongoing government research was aligned with USCAR in the Partnership for the New Generation of Vehicles (see *FreedomCAR* and *PNGV*).

VOCs – Volatile organic chemicals include gasoline, industrial chemicals such as benzene, solvents such as toluene, and the common dry cleaning solvent tetrachlorethylene. Many VOCs do not occur in nature but were synthesized by chemists in laboratories. Volatile chemicals produce vapors and, at room temperature and pressure, vapors can escape easily. They can combine with NO_x in the presence of sunlight to create smog.

WWW -- Wide World Web.